The Use of UV/VIS/NIR Spectroscopy in the Development Of High Efficiency PV Solar Cells.

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1 Introduction

From the start of our busy days to the end, electricity is the life blood that keeps us going. We cook, heat, clean, light, work, communicate and are entertained all driven by electricity. The most common modes of generation are hydro, nuclear geothermal or fossil fuel powered. There is a clear need throughout the world to develop clean renewable sustainable sources of power to support growing economies and reduce our carbon footprint. Solar energy is a developing field with clear advantages for the future. To go main stream however cost parity is needed with other sources of energy.

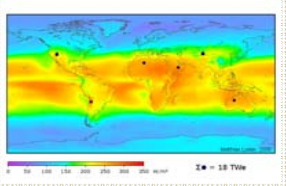


Figure 1. Average solar irradiance, watts per square metre across the globe. The small black dots show the area of solar panels needed to generate all of the worlds energy using 8% eff. PVs. (Wikipedia)

2 PV Cells based on silicon come in several forms

There are two primary types of silicon solar cells. Crystal and thin film based. Key drivers in development are cost and efficiency. Optimization of all materials used in the design and manufacture of these devices is critical to achieve optimum efficiency

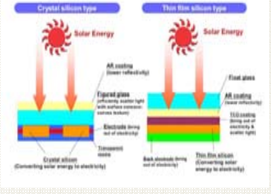


Figure 2. Silicon based solar cells are the most common devices currently in use today.

3 The Search For High Efficiency PV Materials

The current cost differential between solar and conventional energy is on the order of 4x. For solar to reach parity new materials and manufacturing techniques will need to be developed to reduce cost and ease installation.

The solar spectrum has been defined to allow researchers a standard to validate new designs. Air mass 1.5 illumination is the standard typically used in the testing of PV materials and ranges in wavelength from 350-2500nm covering the UV/Vis and a portion of the NIR wavelength region. The photovoltaic output is of key interest and measured in terms of Quantum Efficiency. This is the ratio of electrons immerging from the cell to the number of incident photons.

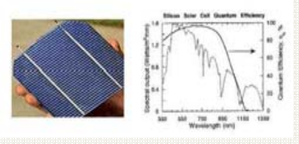


Figure 3. Quantum efficiency curve of a typical silicon PV device overlaid on the standard AM 1.5 curve

4 Multi layer PV cells maximize efficiency across the full solar range

New developments in PV cell design are focused on using multiple thin films designs. Matching the solar performance of these coatings allows the ability to better control the conversion of photons to electrical current gaining the maximum in efficiency.

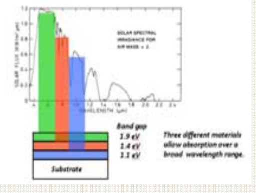
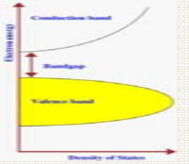


Figure 4. Multi layer thin film coating designs allow PV designs to be optimized to the full solar spectrum by optimizing each layer for a portion of the spectrum. By doing this even in low light conditions energy can still be products.

5 UV/VIS/NIR Spectroscopy a critical tool in the design of PV cells

One of the most common measurements made is the determination of Band Gap properties of a material. This relates to the ease in which a semiconducting material will transfer electrons to it's conducting band. This is fundamental to research on new materials



The solar spectral range, from 350-2500nm is used for the analysis of most materials. This includes not only the PV material but other components such as glass substrates and coatings. The Lambda 1050 equipped with a 150mm integrating sphere is one of the most common platforms to measure the diffuse reflectance and transmission characteristics of solar materials.

Figure 5. The Lambda 1050 equipped with a 150mm integrating sphere which utilizes a PMT for the UV/Vis region and a wideband InGaAs detector providing high sensitivity in the NIR region

Diffuse transmission is the result of light passing through a material which scatters rays of light in all directions. Diffuse reflectance is the result of light reflecting off of a non mirror like surface. Surfaces and coatings like anti reflective coatings are optimized to around these parameters.

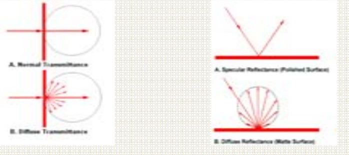
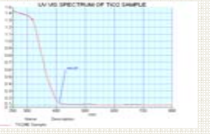


Figure 6. Shown are examples of both diffuse transmission and reflectance characteristics caused by some materials.

6 Example Analysis

Tantania (TiO_2) was used to summarize the typical process for determining the Band Gap of a material. The sample was measured in diffuse reflectance mode on a Lambda 1050 with the data recorded in absorbance. From the spectra below the wavelength at which the sample begins to absorb can clearly be determined. This wavelength is the Cutoff wavelength and is used in the equation below.



Calculations:
Band Gap Energy (E)= h*C/λ
h = Planks constant= 6.626 X 10-34Joules Sec
C = Speed of light = 3.0 X 10 8 meter /sec
λ = Cut off wavelength= 410.57 X 10-9 meters

h	C	λ	E	eV
6.63E-34	3.00E+08	4.11E-07	4.84156E-19	3.025976

Where 1eV= 1eV= 1.6 X 10^{-19} Joules (conversion factor)

Figure 5. The band gap is simply the potential needed to move electron to the conduction band expressed in electron volts.

7 Summary

The development of new and unique materials to increase the efficiency and lower the cost of solar cells continues to be a important R&D activity. Both PV materials and supporting structures require careful spectral characterization to achieve their maximum performance. UV/VIS/NIR is a key technology in providing that understanding.

Measurements critical to the support of PV solar energy now and in the future include:

- Diffuse Reflectance to understand how surface structure impacts light retention and loss.
- Diffuse Transmission to promote the understanding of efficiencies of transparent materials for control and concentration of light.
- Affects of weathering on optical materials for long term outdoor exposure studies
- Thin Film coating characterization

Analysis of anti-reflective coating performance as well as analysis of coating layers on developing thin film cell technology.

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